

REMARKS

I. Summary of the Invention

The invention relates generally to a pressure seal for containing fluid pressure at an annular interface having a metal-to-metal contact with one or more metal annular members. (Specification, page 2, lines 8 to 11.) In particular, it is desired to make a proper metal-to-metal seal in a pipe connector of the kind that forms a pressure seal by wedging a metal seal ring between two hubs, and to permit the metal-to-metal seal to be broken and later properly reset. (Specification, page 2, lines 17 to 20 and page 3, lines 6 to 10.)

To solve these problems, there is provided a composite metal seal (15) that includes a core (34) of relatively hard metal, and at least one annular region (35, 36) of relatively soft metal. The annular region of relatively soft metal is integrally bonded with the core of relatively hard metal, and has an annular sealing surface (32, 33) for providing a fluid pressure seal. (Specification, page 4, lines 19 to 24; page 13 line 23 to page 14 line 10; FIG. 3.) In the preferred construction, the annular region of relatively soft metal 35, 36 is welded onto the relatively hard metal core 14. (Specification, page 17, lines 8 to 16; FIG. 6.)

The applicant's invention provides a number of advantages. The composite metal seal ring 15 functions as an integral piece of metal, although the properties of the metal are different in different regions of the composite metal seal ring. (Specification, page 17, lines 13 to 16.) The soft overlay metal can flow into any discontinuity that may exist in the hub seal surfaces and effect a seal. Moreover, the soft overlay metal will not scratch or impinge the hub sealing surfaces. (Specification, page 14, lines 7 to 10.) The hard metal core 34 ensures that there can be a relatively high contact stress between the metal seal ring 15 and the hub sealing surfaces. The high compressive stress in the seal enhances the seal's ability to withstand any external

pressure, and internal pressure further energizes the seal. By overlaying a high strength core, the high strength capacity of the seal is maintained and a softer exterior surface is presented that will deform prior to deformation of the hub surfaces. Therefore, the hard metal core 34 ensures that the seal ring can be used after making and breaking the metal seal numerous times.

(Specification, page 14, lines 11 to 21.)

II. Issues

A. Is it proper to interpret “integrally bonded” to mean merely that the hard and soft metal of the composite metal seal ring are held next to each other or are in contact?

B. It is proper to modify Fyffe U.S. 1,426,724 in view of Bloom 5,680,495 so as to reconstruct the applicant’s claimed invention?

ARGUMENT

A. It is improper to interpret “integrally bonded” to mean merely that the hard and soft metal of the composite metal seal ring are held next to each other or are in contact.

Paragraph 9 on page 7 of the Final Official Action says: “Argument concerning integrally bonded is not persuasive because integrally bonded interpreted broadly can mean that the hard and soft metal of the composite metal seal ring are held next to each other or are in contact.” Applicant respectfully disagrees. Such an interpretation is an unreasonably broad interpretation.

According to the Manual of Patent Examining Procedure, Section 2111:

The broadest reasonable interpretation of the claims must also be consistent with the interpretation that those skilled in the art would reach. In re Cortright, 165 F.3d 1353, 1359, 49 USPQ2d 1464, 1468 (Fed. Cir. 1999)(The Board's construction of the claim limitation "restore hair growth" as requiring the hair to be returned to its original state was held to be an unreasonably broad interpretation of the limitation. The court held that, consistent with applicant's disclosure and the disclosure of three patents from analogous arts using the same phrase to require only some increase in hair growth, one of ordinary skill would construe "restore hair growth" to mean that the claimed method increases the amount of hair grown on the scalp, but does not necessarily produce a full head of hair.)

The specification as originally filed, page 17, lines 8 to 16, uses the term "integral bond" in the following fashion:

A preferred method of fabricating the composite metal seal ring 15 includes a welding overlay process. This welding process deposits the relatively soft metal overlay 35, 36 onto the relatively hard metal core 34 in such a way as to produce an integral bond between them. In other words, the composite metal seal ring 15 functions as an integral piece of metal, although the properties of the metal are different in different regions of the composite metal seal ring. (Emphasis added.)

The applicants' usage of the term "integral bond" is consistent with the common meaning of the terms "integral" and 'bond" and therefore must be given legal effect. See, for example, the enclosed pages 168 and 738 from Webster's Encyclopedic Unabridged Dictionary of the English Language, Random House, New York, New York, 1989. The applicable definition of "bond" includes "14: adhesion between two substances or objects." The applicable definition of "integral" includes "3: made up of parts which together constitute a whole."

See also M.P.E.P. 2111.01:

APPLICANT MAY BE OWN LEXICOGRAPHER

Applicant may be his or her own lexicographer as long as the meaning assigned to the term is not repugnant to the term's well known usage. *In re Hill*, 161 F.2d 367, 73 USPQ 482 (CCPA 1947). Any special meaning assigned to a term "must be sufficiently clear in the specification that any departure from common usage would be so understood by a person of experience in the field of the invention." *Multiform Desiccants Inc. v. Medzam Ltd.*, 133 F.3d 1473, 1477, 45 USPQ2d 1429, 1432 (Fed. Cir. 1998).

A hard metal object and a soft metal object merely held next to each other or in contact with each other do not have adhesion between them, and the two objects do not constitute a whole. Such a pair of metal objects do not function as an integral piece of metal, as required by the applicant's specification. The definition of "integral bond" proposed in the Final Official Action is inconsistent with the usage of the term in the applicant's specification. It renders the word "integral" meaningless. It is inconsistent with the interpretation that those skilled in the art would reach. Therefore, such an interpretation is an unreasonably broad interpretation.

B. It is improper to modify Fyffe U.S. 1,426,724 in view of Bloom 5,680,495 so as to reconstruct the applicant's claimed invention.

The Final Official Action, paragraph 5 on page 5, relies on Bloom for showing "a deformable metal seal (70), where a soft metal is welded onto a relatively hard metal (metal layer 76 and 78)." However, Bloom describes (70) as "a deformable metal layer " that "comprises a first layer 76 and a second layer 78" and that are "overlaying the [substrate] body 74." (Bloom, col. 6, lines 26-29.) In other words, the layers 76 and 78 are layers on a substrate body 74, and

two substrate bodies are bonded together to hermetically seal a fiber optic device. (See the abstract and FIG. 9.) Moreover, there is nothing in Bloom disclosing that the inner metal layer 76 is a relatively hard metal layer, and the outer metal layer 78 is a relatively soft metal layer. For example, the inner metal layer 76 consists essentially of pure aluminum, and the outer metal layer 78 consists essentially of gold. (Bloom, col. 6, lines 33-35.) One would expect pure aluminum and pure gold to have similar hardness, but essentially pure aluminum may be softer than essentially gold. See also the enclosed two pages 28-43 and 28-48 from Perry's Chemical Engineer's Handbook, Seventh Edition, McGraw-Hill, 1997, disclosing a hardness of 19 for min 99.6% pure aluminum AA designation 1060 (right-hand column of Table 28-16) and a hardness of 25 for min 99.95 % annealed gold designation UNS P00020 (right-hand column in Table 28-19). In this case, a harder metal layer (essentially gold) would be overlaid on a softer metal layer (essentially pure aluminum). Moreover, Bloom Col. 6 lines 61-62 appears to refer to the ultrasonic welding of contacting outer metal layers 70 at the complementary middle regions 72, creating a hermetic seal between the substrates 64a and 64b along the middle surface 72. (Bloom, col. 6, lines 49-56.) Furthermore, the very thin metal layers in the miniature electronic device of Bloom are not analogous to the hard and soft metal regions of the applicant's claimed invention.

In paragraph 5, on page 5, the Final Official Action concludes: "It would have been obvious to one having ordinary skill in the art at the time of the invention was made to have the relatively hard metal and the relatively soft metal of Fyffe to be welded to each other, to provide a hermetic seal and gas tight seal (a seal having metal layers 76 and 78 to be bonded by welding, column 6, lines 17-23, lines 31-28, lines 51-53 and 60-63)." However, it is not seen how the advantage of hermetic sealing of a miniature solid-state electronic device would provide a proper

motivation for modifying the pipe joint seal of Fyffe, nor would the proposed application of the teaching of hermetic sealing to a pipe joint result in applicant's claimed invention. It is not evident from the cited references where Fyffe is deficient in its intended purpose of making a pipe connection that is not necessarily permanent. Moreover, if one wants to hermetically seal a joint between metal pipes, in accordance with the proposed teaching of Bloom, it is not seen why one would deviate from the common practice of simply welding the pipes to each other.

The policy of the Patent and Trademark Office has been to follow in each and every case the standard of patentability enunciated by the Supreme Court in Graham v. John Deere Co., 148 U.S.P.Q. 459 (1966). M.P.E.P. § 2141. As stated by the Supreme Court:

Under § 103, the scope and content of the prior art are to be determined; differences between the prior art and the claims at issue are to be ascertained; and the level of ordinary skill in the pertinent art resolved. Against this background, the obviousness or nonobviousness of the subject matter is determined. Such secondary considerations as commercial success, long felt but unsolved needs, failure of others, etc., might be utilized to give light to the circumstances surrounding the origin of the subject matter sought to be patented. As indicia of obviousness or nonobviousness, these inquiries may have relevancy.

148 U.S.P.Q. at 467.

The problem that the inventor is trying to solve must be considered in determining whether or not the invention would have been obvious. The invention as a whole embraces the structure, properties and problems it solves. In re Wright, 848 F.2d 1216, 1219, 6 U.S.P.Q.2d 1959, 1961 (Fed. Cir. 1988).

For the teachings of a reference to be prior art under 35 U.S.C. §103, there must be some basis for concluding that the reference would have been considered by one skilled in the particular art working on the particular problem with which the invention pertains. In re Horne, 203 U.S.P.Q. 969, 971 (C.C.P.A. 1979). Non-analogous art cannot properly be pertinent prior art under 35 U.S.C.

§103. In re Pagliaro, 210 U.S.P.Q. 888, 892 (C.C.P.A. 1981). The determination of whether a reference is from a non-analogous art is a two-step test as set forth in Union Carbide Corp. v. American Can Co., 724 F.2d 1567, 1572, 220 U.S.P.Q. 584, 588 (Fed. Cir. 1984). In Union Carbide, the court found that the first determination was whether "the reference is within the field of the inventor's endeavor." If it is not, one must proceed to the second step "to determine whether the reference is reasonably pertinent to the particular problem with which the inventor was involved." Id. "[T]he purposes of both the invention and the prior art are important in determining whether the reference is reasonably pertinent to the problem the invention attempts to solve." In re Clay, 966 F.2d 656, 659, 23 U.S.P.Q.2d 1058, 1061 (Fed. Cir. 1992).

In the present case, the applicant's invention is directed to a pressure seal for containing fluid pressure at an annular interface having a metal-to-metal contact with one or more metal annular members. Fyffe is in the applicant's field of endeavor, but Bloom is not. For example, Bloom is classified in class 385 (Optical Waveguides), and Bloom's field of search further includes class 372 (Coherent Light Generators), class 257 (Active solid-state devices, e.g., transistors, solid-state diodes), and class 437 [438? (Semiconductor device manufacturing: process)].

Bloom is not reasonably pertinent to the particular problem with which the inventor was involved. Among other things, Bloom is directed to sealing a fiber optic device by compressed metal seals; in other words, encapsulating and sealing a miniature solid-state electronic device from the surrounding environment. This is not reasonably pertinent to the applicant's problem of improving a pressure seal for containing fluid pressure at an annular interface having a metal-to-metal contact with one or more metal annular members in order to permit the metal-to-metal seal to be broken and later properly reset. There is no basis for concluding that Bloom would have

been considered by one skilled in the pipe seal art working on the particular problem with which the applicant's invention pertains.

Even if there would be some basis for concluding that a person of ordinary skill in the art would have considered Bloom, there is nothing in the prior art as a whole suggesting the desirability of modifying Fyffe in view of Bloom. Fyffe appears to be entirely satisfactory for its intended purpose of providing a pressure seal for containing fluid pressure at an annular interface having a metal-to-metal contact with one or more metal annular members in order to permit the metal-to-metal seal to be broken and later properly reset. Bloom relates to hermetically sealing a miniature solid-state electronic device from its surrounding environment. If a person of ordinary skill in the pipe seal art would be told to apply a teaching from Bloom to provide a hermetic and gas tight pipe seal by welding, it is not seen why the person of ordinary skill in the pipe seal art would deviate from the common practice of simply welding the pipes to each other.

It appears that the only motivation for modifying Fyffe to arrive at the applicant's invention is the applicant's own novel disclosure of welding a relatively soft annular metal overlay onto a relatively hard metal core. However, it is improper to attempt to establish obviousness by using the applicant's specification as a guide to combining different prior art references to achieve the results of the claimed invention. Orthopedic Equipment Co., Inc. v. United States, 702 F.2d 1005, 1012, 217 U.S.P.Q. 193, 199 (Fed. Cir. 1983). Hindsight reconstruction, using the applicant's specification itself as a guide, is improper because it fails to consider the subject matter of the invention "as a whole" and fails to consider the invention as of the date at which the invention was made. The critical inquiry is whether there is something in the prior art as a whole to suggest the desirability, and thus the obviousness, of making the combination. In re Dembiczak, 175 F.3d 994, 999-1000, 50 U.S.P.Q.2d 1614, 1617 (Fed. Cir. 1999)(actual evidence and particular findings

need to support the PTO's obviousness conclusion); Interconnect Planning Corp. v. Feil, 774 F.2d 1132, 1138, 227 U.S.P.Q. 543, 547 (Fed. Cir. 1985) ("The invention must be viewed not with the blueprint drawn by the inventor, but in the state of the art that existed at the time."); In re Fritch, 972 F.2d 1260, 1266, 23 U.S.P.Q.2d 1780, 1784 (Fed. Cir. 1992) ("It is impermissible to use the claimed invention as an instruction manual or 'template' to piece together the teachings of the prior art so that the claimed invention is rendered obvious."); Fromson v. Advance Offset Plate, Inc., 755 F.2d 1549, 1556, 225 U.S.P.Q. 26, 31 (Fed. Cir. 1985) (nothing of record plainly indicated that it would have been obvious to combine previously separate lithography steps into one process). See, for example, In re Gordon et al., 733 F.2d 900, 902, 221 U.S.P.Q. 1125, 1127 (Fed. Cir. 1984) (mere fact that prior art could be modified by turning apparatus upside down does not make modification obvious unless prior art suggests desirability of modification); Ex Parte Kaiser, 194 U.S.P.Q. 47, 48 (PTO Bd. of Appeals 1975) (Examiner's failure to indicate anywhere in the record his reason for finding alteration of reference to be obvious militates against rejection).

In short, annular seals for coupling metal tubular members as in Fyffe, and welding techniques for joining metal tubular members, have been known for about 80 years since Fyffe, yet none of the art cited by the examiner applicable to annular seals suggests the applicant's invention, which admittedly offers significant advantages over the prior art. This is objective evidence of the patentability of the applicant's invention. Fromson v. Advance Offset Plate, Inc., 755 F.2d 1549, 1557, 225 U.S.P.Q. 26, 32-33 (Fed. Cir. 1985) (It is at best bizarre to assert that the subject matter claimed was merely an obvious extension of technology when none skilled in the art attempted such "extension" during the seven years when alleged economic advantages of such technology were available).

In view of the above, it is respectfully submitted that the application is in condition for allowance. Early allowance is earnestly solicited.

Respectfully submitted,



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APPENDIX I. VERSION WITH MARKINGS TO SHOW CHANGES MADE

4. (Once Amended) [The composite metal seal as claimed in claim 1] A composite metal seal comprising a core of relatively hard metal, and at least one annular region of relatively soft metal that is integrally bonded with the core of relatively hard metal and that provides an annular sealing surface for effecting a fluid pressure seal, wherein the annual region of relatively soft metal is welded onto the core of relatively hard metal.

11. (Once Amended) [The composite metal seal ring as claimed in claim 8] A composite metal seal ring for effecting a fluid pressure seal with respective annular surfaces of first and second hub members, the composite metal seal ring comprising an annular core of relatively hard metal, a first annular region of relatively soft metal integrally bonded to the annular core of relatively hard metal, and a second annular region of relatively soft metal integrally bonded to the annular core of relatively hard metal, the first annular region of relatively soft metal having a first annular surface for mating with the annular surface of the first hub member to effect a fluid pressure seal with the first hub member, and the second annular region of relatively soft metal having a second annular surface for mating with the annular surface of the second hub member to effect a fluid pressure seal with the second hub member, wherein the two annular regions of relatively soft metal are displaced from each other along a longitudinal axis of the composite metal seal ring, wherein the first annual region of relatively soft metal is welded onto the annular core of relatively hard metal, and the relatively soft metal of the second annular region of relatively soft metal is welded onto the annular core of relatively hard metal.

26. (Once Amended) [The composite metal seal ring as claimed in claim 21,] A composite metal seal ring for effecting a resettable fluid pressure seal with respective annular surfaces of first and second hub members, the composite metal seal ring comprising an annular core of relatively hard metal, a first annular region of relatively soft metal integrally bonded to the annular core of relatively hard metal, and a second annular region of relatively soft metal integrally bonded to the annular core of relatively hard metal, the first annular region of relatively soft metal having a first annular surface for mating with the annular surface of the first hub member to effect a fluid pressure seal with the first hub member, and the second annular region of relatively soft metal having a second annular surface for mating with the annular surface of the second hub member to effect a fluid pressure seal with the second hub member, wherein the two annular regions of relatively soft metal are displaced from each other along a longitudinal axis of the composite metal seal ring;

wherein the first annular region of relatively soft metal has a thickness in said radial direction of at least one-eighth of an inch, and the second annular region of relatively soft metal has a thickness in said radial direction of at least one-eighth of an inch;

wherein the annular core of relatively hard metal is inlaid and overlaid with the relatively soft metal of the first annular region of relatively soft metal, and the annular core of relatively hard metal is inlaid and overlaid with the relatively soft metal of the second annular region of relatively soft metal;

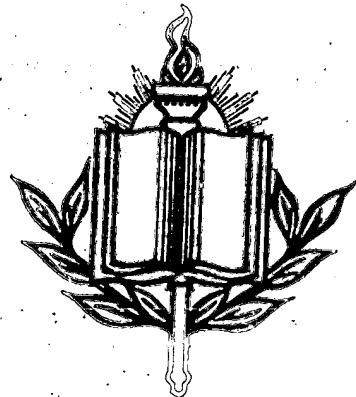
wherein the first annual region of relatively soft metal is welded onto the annular core of relatively hard metal, and the relatively soft metal of the second annular region of relatively soft metal is welded onto the annular core of relatively hard metal;

wherein the composite metal seal ring has a longitudinal axis, and the annular surface of the first annular region of relatively soft metal is tapered with respect to the longitudinal axis to have a varying radius that is smallest away from the second annular region of relatively soft metal and that is largest toward the second annular region of relatively soft metal, and the annular surface of the second annular region of relatively soft metal is tapered with respect to the longitudinal axis to have a varying radius that is smallest away from the first annular region of relatively soft metal and that is largest toward the first annular region of relatively soft metal; and

wherein the composite metal seal ring is adapted for containing a pressure within the hubs of at least 10,000 psi, the composite metal seal ring has an internal diameter of at least 3 inches, and the composite metal seal ring is a hybrid of a pressure energized seal type AX and a compression seal type BX.



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TABLE 28-16 Aluminum Alloys

AA designation	UNS	Composition, %*						Condition†	Mechanical properties‡				
		Cr	Cu	Mg	Mn	Si	Other		Yield strength, kip/in ² (MPa)	Tensile strength, kip/in ² (MPa)	Elongation in 2 in, %	Hardness HB	
Brought													
1060	A91060		0.05-0.2					99.6 Al min.	0	4 (28)	10 (69)	43	19
1100	A91100			3.8-4.9	1.2-1.8	0.3-0.9	0.5	99.0 Al min.	0	5 (34)	13 (90)	45	23
2024	A92024	0.1				1.0-1.5	0.6		T4	47 (324)	68 (469)	19	120
3003	A93003		0.05-0.2						H14	21 (145)	22 (152)	16	40
5052	A95052	0.15-0.35	0.1	2.2-2.8	0.1				0	13 (90)	2.8 (193)	30	47
5083	A95083	0.05-0.25	0.1	4.0-4.9	0.4-1.0	0.4			0	21 (145)			
5086	A95086	0.05-0.25	0.1	3.5-4.5	0.2-0.7	0.4			0	17 (117)	38 (262)	30	
5154	A95154	0.05-0.35	0.1	3.1-3.9	0.1	0.25			0	17 (117)	35 (241)	27	58
6061	A96061	0.04-0.35	0.15-0.4	0.8-1.2	0.15	0.4-0.8			T6	40 (276)	45 (310)	17	95
6063	A96063	0.1	0.1	0.45-0.9	0.1	0.2-0.6			T6	31 (214)	35 (241)	18	73
7075	A97075	0.18-0.28	1.2-2.0	2.1-2.9	0.3	0.40		5.1-6.1 Zn	T6	73 (503)	63 (572)	11	150
Cast													
242.0	A02420	0.25	3.5-4.5	1.2-1.8	0.35	0.7		1.7-2.3 Ni	S-T571		29 (200)		
295.0	A02950		4.0-5.0	0.03	0.35	0.7-1.5			S-T4		29 (200)	6	
A332.0	A13320		0.5-1.5	0.7-1.3	0.35	11-13		2.0-3.0 Ni	P-T551		31 (214)		
B443.0	A24430		0.15	0.05	0.35	4.5-6.0			S-F		17 (117)	3	
514.0	A05140		0.15	3.5-4.5	0.35	0.35			S-F		22 (152)	6	
520.0	A05200		0.25	9.5-10.6	0.15	0.25			S-T4		42 (290)	12	

*Single values are maximum values.

†Typical room-temperature properties.

‡S = sand-cast; P = permanent-mold-cast; other = temper designations.

SOURCE: Aluminum Association. Courtesy of National Association of Corrosion Engineers. To convert MPa to lbf/in², multiply by 145.04.

on plastic. This membrane functions as a barrier to protect the substrate from corrosion damage. A special prestressed-brick design that maintains the brick in compression by using a controlled-expansion resinous mortar and brick bedding material precludes the use of an elastomeric membrane.

Cement and Concrete Concrete is an aggregate of inert reinforcing particles in an amorphous matrix of hardened cement paste. Concrete made of portland cement has limited resistance to acids and bases and will fail mechanically following absorption of crystallizing solutions such as brines and various organics. Concretes made of corrosion-resistant cements (such as calcium aluminate) can be selected for specific chemical exposures.

Soil Clay is the primary construction material for settling basins and waste-treatment evaporation ponds. Since there is no single type of clay even within a given geographical area, shrinkage, porosity, absorption characteristics, and chemical resistance must be checked for each application.

ORGANIC NONMETALLICS

Plastic Materials In comparison with metallic materials, the use of plastics is limited to relatively moderate temperatures and pressures [230°C (450°F) is considered high for plastics]. Plastics are also less resistant to mechanical abuse and have high expansion rates, low strengths (thermoplastics), and only fair resistance to solvents. However, they are lightweight, are good thermal and electrical insulators, are easy to fabricate and install, and have low friction factors.

Generally, plastics have excellent resistance to weak mineral acids and are unaffected by inorganic salt solutions—areas where metals are not entirely suitable. Since plastics do not corrode in the electrochemical sense, they offer another advantage over metals: most metals are affected by slight changes in pH, or minor impurities, or oxygen content, while plastics will remain resistant to these same changes.

The important thermoplastics used commercially are polyethylene, acrylonitrile butadiene styrene (ABS), polyvinyl chloride (PVC), cellulose acetate butyrate (CAB), vinylidene chloride (Saran), fluorocarbons (Teflon, Halar, Kel-F, Kynar), polycarbonates, polypropylene, nylons, and acetals (Delrin). Important thermosetting plastics are

general-purpose polyester glass reinforced, bisphenol-based polyester glass, epoxy glass, vinyl ester glass, furan and phenolic glass, and asbestos reinforced.

THERMOPLASTICS

The most chemical-resistant plastic commercially available today is **tetrafluoroethylene** or **TFE** (Teflon). This thermoplastic is practically unaffected by all alkalies and acids except fluorine and chlorine gas at elevated temperatures and molten metals. It retains its properties up to 260°C (500°F). **Chlorotrifluoroethylene** or **CTFE** (Kel-F, Plaskon) also possesses excellent corrosion resistance to almost all acids and alkalies up to 180°C (350°F). A Teflon derivative has been developed from the copolymerization of tetrafluoroethylene and hexafluoropropylene. This resin, **FEP**, has similar properties to TFE except that it is not recommended for continuous exposures at temperatures above 200°C (400°F). Also, FEP can be extruded on conventional extrusion equipment, while TFE parts must be made by complicated powder-metallurgy techniques. Another version is **polyvinylidene fluoride**, or **PVF₂** (Kynar), which has excellent resistance to alkalies and acids to 150°C (300°F). It can be extruded. A more recent development is a copolymer of CTFE and ethylene (Halar). This material has excellent resistance to strong inorganic acids, bases, and salts up to 150°C. It also can be extruded.

Perfluoroalkoxy, or **PFA** (Teflon), has the general properties and chemical resistance of FEP at a temperature approaching 300°C (600°F).

Polyethylene is the lowest-cost plastic commercially available. Mechanical properties are generally poor, particularly above 50°C (120°F), and pipe must be fully supported. Carbon-filled grades are resistant to sunlight and weathering.

Unplasticized polyvinyl chlorides (type I) have excellent resistance to oxidizing acids other than concentrated and to most nonoxidizing acids. Resistance is good to weak and strong alkaline materials. Resistance to chlorinated hydrocarbons is not good. Polyvinylidene chloride, known as **Saran**, has good resistance to chlorinated hydrocarbons.

Acrylonitrile butadiene styrene (ABS) polymers have good resistance to nonoxidizing and weak acids but are not satisfactory with oxidizing acids. The upper temperature limit is about 65°C (150°F).

TABLE 28-19 Miscellaneous Alloys*

Alloy	Designation	UNS	Composition, %†	Condition	Mechanical properties‡			
					Yield strength, kip/in. ² (MPa)	Tensile strength, kip/in. ² (MPa)	Elongation, %	Hardness, HB
Refractory alloys								
Niobium R04210 (columbium)		204-210	99.6Cb 0.01-0.04C	Annealed	37 (255)	53 (365)	26	80
Molybdenum	R03600		0.01C	Annealed				
Molybdenum, low C	R03650		0.01-0.04C, 0.40-0.55Ti, 0.06-0.12Zn	Annealed				
Molybdenum alloy	R03630		99.8 min. Ta	Annealed				
Tantalum	R05200		99.9 min. W	Annealed				
Tungsten	R07300		4.5 Hf, 0.2 Fe + Cr, 99.2 Zi + Hf	Annealed				
Zirconium	R60702							
Precious metals and alloys								
Gold	P00020	99.95 min. Au	Annealed	37 (255)	53 (365)	26	80	
Silver	P07015	99.95 min. Ag	Annealed					
Stirling silver	P04955	7.5 Cu, 92.5 Ag	Annealed					
Platinum	P03980	99.95 min. Pt	Annealed					
Palladium	P0980	99.80 min. Pd	Annealed					
Lead alloys								
Chemical lead		99.9 min. Pb	Rolled	1.9 (13)	2.5 (17)	50	5	
Antimonial lead		90 Pb, 10 Sb	Rolled	4.1 (28)	4.7	13		
Tellurium lead		99.85 Pb, 0.04 Te	Rolled	3.2 (21)	4.5	6		
50-50 solder	L05500	0.06 Cu 50 Pb, 50 Sn, 0.12 max. Sb	Cast	6.8 (47)	50	14		
Magnesium alloys								
Wrought alloy	A231B	M11311	2.5-3.5 Al, 0.20 min. Mn, 0.6-1.4 Zn	Annealed	15-18 (103-124)	32 (220)	9-12	56
Cast alloy	A291C	M11914	8.1-9.3 Al, 0.13 min. Mn, 0.4-1.0 Zn	As cast	11 (76)	23 (158)		60
Cast alloy	E232A	M12330	2.0-3.1 Zn, 0.5-1.0 Zr	Aged	14 (97)	20 (138)	2	50
Wrought alloy	HK31A	M13310	0.3 Zn, 2.5-4.0 Th, 0.4-1.0 Zr	Stress hard-annealed	24-26 (165-179)	33-34 (228-234)	4	57
Titanium alloys								
Commercial pure	Cr. 1	R50250	0.20 Fe, 0.18 O	Annealed	35 (241)	48 (331)	30	120
Commercial pure	Cr. 2	R50400	0.30 Fe, 0.25 O	Annealed	50 (345)	63 (434)	28	200
Ti-Pd	Cr. 7	R52400	0.30 Fe, 0.25 O, 0.12-0.25 Pd	Annealed	50 (345)	63 (434)	28	200
Ti-6Al-4V	Cr. 5	R56400	5.5-5.6 Al, 0.40 Fe, 0.20 O, 3.5-4.5 V	Annealed	134 (924)	144 (983)	14	330
Low alloy	Cr. 12		0.2-0.4 Mo, 0.6-0.9 Ni	Annealed	65 (448)	75 (517)	25	
Cobalt alloys								
N-155	R30155	0.08-0.16 C, 0.75-1.25 Cr, 18.50-21.0 Co, 20.0-22.5 Cr, 1.0-2.0 Mn, 2.5-3.5 Mo, 19-21 Ni, 1.0 Si, 2.0-3.0 W	Annealed	35 (241)	48 (331)	30	120	
MP35N	R30036	0.025 C, 19-21 Cr, 1.0 Fe, 0.15 Mn, 9.0-10.5 Mo, 33.37 Ni, 0.15 Si, 1.0 Ti	Annealed	60 (414)	135 (931)	28	200	
Stellite 6	R30006	0.9-1.4 C, 27-31 Cr, 3 Fe, 1.0 Mn, 1.5 Mo, 3.0 Ni, 1.5 Si, 3.5-5.5 W	As cast	105 (724)	105 (724)	1	330	

*Courtesy of National Association of Corrosion Engineers. To convert MPa to lb/in.², multiply by 145.04.

†Typical room-temperature properties.

‡Single values are maximum values unless otherwise noted.

TABLE 28-20 Properties

Specific gravity, 77°F
Water absorption, %
Gas permeability
Softening temperature, °F
Specific heat, 77°F Btu/lb
Mean specific heat (77-752)
Thermal conductivity, mean Btu/(ft ² ·h·°F)/in [W/(m·K)]
Linear thermal expansion, 1/ ^o F (°C) × 10 ⁻⁶
Modulus of elasticity, kip/in. ²
Poisson's ratio
Modulus of rupture, kip/in. ²
Knoop hardness, 100 g
Knoop hardness, 500 g
Adhesion strength kip/in. ²
Maximum operating temperature
Thermal shock resistance, °F (°C)

*Courtesy of National Aeronautics and Space Administration.

treated acids, except nitric acid, known as polysiloxanes at temperatures as well as a **Chlorosulfonated polyethylene** having resistance to ozone and sulfuric acids. Oil resistance is excellent. Kel-F, Kalrez, and Viton are some of the materials that overcome some of the resistance.

The **cis-polybutene-1-propylene** rubbers are ethylene-propylene rubber and oxidation.

TABLE 28-21 Chemical resistance

	Polypropylene	Polyethylene
10% H ₂ SO ₄	Excel	Excel
50% H ₂ SO ₄	Excel	Excel
10% HCl	Excel	Excel
10% HNO ₃	Excel	Excel
10% Acetic acid	Excel	Excel
10% NaOH	Excel	Excel
50% NaOH	Excel	Excel
NH ₄ OH	Excel	Excel
NaCl	Excel	Excel
FeCl ₃	Excel	Excel
CuSO ₄	Excel	Excel
NH ₄ NO ₃	Excel	Excel
Wet H ₂ S	Poor	Excel
Wet Cl ₂	Poor	Excel
Wet SO ₂	Poor	Excel
Gasoline	Poor	Poor
Benzene	Poor	Poor
CCl ₄	Poor	Poor
Acetone	Poor	Poor
Alcohol	Poor	Poor

NOTE: Ratings are for:

*Cellulose acetate butyrate

†Acrylonitrile butadiene styrene

‡Polyvinyl chloride, tyvek

§Chemical resistance

¶Refers to general-purpose